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LITERATURE STUDY ON ENERGY CONSERVATION IN GYPSUM BOARD MANUFACTURE THROUGH REDUCTION OF THE WATER DEMAND OF CALCINED GYPSUM

L' ETUDE DE LA LITERATURE SUR LA CONSERVATION DE L'ENERGIE DANS LA FABRICATION DES PLAQUES DE PLÂTRE PAR LA REDUCTION DE L'EAU DEMANDE DU GYPSE CALCINÉ.

Final Report

By

Ontario Research Foundation
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Mineral Resources Centre

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EXECUTIVE SUMMARY

The production of gypsum board is an energy intensive process and increasing fuel costs have prompted manufacturers to investigate methods of reducing the energy requirements of board manufacture. This report addresses current research in energy conservation in gypsum board manufacture through reduction of stucco water demand. The project consists of a review of published information and information obtained from the gypsum board manufacturers. A critical review of the acquired information is presented. New, but unproven theories which may have potential for use in the Canadian gypsum board industry are also discussed.

RÉSUMÉ EXÉCUTIF

La production des plaques de plâtre est une procédure d' energie intensive et d'un coût croissant du fuel qui incitent les fabricant à examiner sur les méthodes de réduire les requis d'energie dans la manufacture des plaques de plâtre. Ce rapport s'adresse à une présente recherche dans la conservation de l'energie dans la fabrication des plaques de plâtre par la réduction de la demande d'eau stucco. Le project consiste à une revue de l'information déjà publiée et d'information déjà obtenu par les fabricants des plaques de plâtre. Une revue critique sur l'information acrue est présentée. Ces théories nouvelles mais sans preuve qui peuvent avoir du potential dans le domaine de l'industrie canadienne des plaques de plâtre sont aussi discutées.

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EXECUTIVE SUMMARY

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1. INTRODUCTION

The gypsum industry is among the top five energy consumers in the Canadian non-metallic minerals sector. Its annual energy consumption of 5.5 to 6 million G.J. places it in the same category as the lime and asbestos industries. The processing of gypsum rock into gypsum board requires several steps, these being grinding, calcining, mixing the calcined material with water to form a slurry, casting this slurry between sheets of paper and, finally, cutting and drying the board. Of these processing steps, the drying of the gypsum board requires approximately 70% of the total process energy. This project addresses the reduction of drying energy through the reduction in the water content of the gypsum slurry.

2. OBJECTIVES

The objectives of this project were:

- to investigate methods of stucco water demand reduction using published information;

- to contact Canadian gypsum companies to learn what methods of stucco water demand reduction are in use;

- to use information acquired to publish a critical review on the state of the art in this field including methods, not proven, but with a high potential for being used in the Canadian gypsum board industry.

3. LITERATURE SEARCHING METHODS

3.1 Literature Search

A literature search was performed using the CAN/OLE information service. The databases searched were Chemical Abstracts (1973 - present) and Engineering Index (1970 - present). The search profile was as follows.

Set Number	Subject
1	Gypsum
2	Plaster
3	Stucco
4	Calcium Sulfate
5	Disintegration
6	Water Demand
7	Consistency
8	Dispersion
9	Energy Conservation
10	Cost Reduction
11	1 + 2 + 3 + 4
12	5 + 6 + 7 + 8
13	9 + 10
14	11 Intersect 12
15	11 Intersect 13

The details of publications contained in sets 14 and 15 were ordered off-line. A total of 77 titles were extracted by the literature search. Approximately 25% of these titles were considered sufficiently relevant to obtain the abstracts and, if possible, the actual publications. If a publication was both in a foreign language and difficult to obtain, only the abstract was used in the writing of the literature review.

3.2 Contact with Gypsum Board Manufacturers

Producers of gypsum board were contacted to learn of the methods of stucco water demand reduction presently employed. The United States Gypsum Company in Libertyville, Illinois and Westroc Industries Ltd., of Mississauga, Ontario provided information for this report.

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4. ENERGY CONSERVATION IN GYPSUM BOARD MANUFACTURE THROUGH REDUCTION OF THE WATER DEMAND OF CALCINED GYPSUM

4.1 Introduction

The gypsum board industry is very competitive in Canada. With three large manufacturers able to serve all major markets in the country, board prices are kept to a minimum. This low profitability, coupled with a quality sensitive consumer (the drywall contractor), forces the manufacturers to search for cost savings measures having minimal effect on the product quality.

This report addresses the potential cost savings measures through reduction in energy consumption in gypsum board manufacture. Specifically, the energy savings through reduction of water demand of calcined gypsum will be investigated.

4.2 Background Information

The manufacture of gypsum board begins with the mining of the raw material, gypsum. The subsequent processing steps and their relative energy requirements are illustrated in figure 1. The coarse material from the mines is transported to the plant where it is dried and finely ground. These initial processing steps require about 6% of the total energy that will be used in the manufacture of gypsum board.

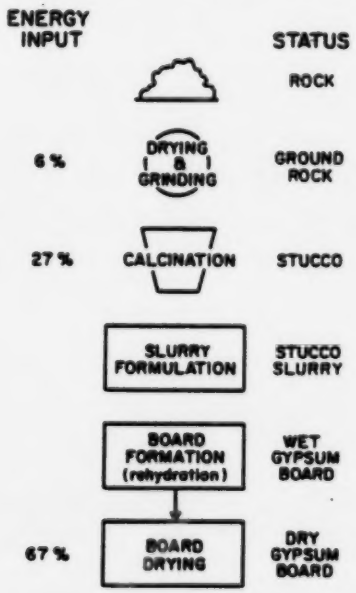

Figure 1: Gypsum Board Manufacture: Energy Consumption of Process Steps

The next step involves the calcining of the raw gypsum at temperatures between 120 and 180°C. The calcination process removes some of the water of hydration from the crystal lattice of the gypsum as follows:

$$CaSO_4.2H_2O \rightarrow CaSO_4.1/2H_2O+3/2H_2O.$$

This process accounts for approximately 27% of the total energy input. The calcined gypsum or stucco is then mixed with water to form a slurry. At this point slurry additives such as reinforcing fibres, set control agents, surface active agents, dispersants and foaming agents are incorporated into the mix. These additives influence the properties of both the slurry and the final product. Although the formation of the slurry (and board) consume some energy, the total amount consumed is relatively small and is not considered to be significant.

Once mixed, the slurry is cast between two sheets of paper where the stucco rehydrates to the dihydrate form. Of the total slurry water, only about 19% is required to hydrate the stucco. The remaining water is necessary firstly to form a slurry of sufficient fluidity to be cast and secondly to wet the paper such that adequate bond strength between the gypsum core and paper is achieved. The excess water must be removed from the board in high temperature dryers. This energy intensive step consumes 67% of the total energy requirements of gypsum board manufacture.

4.3 Energy Reduction in Gypsum Board Manufacture - Current Areas of Study

Reports to the U.S. Federal Energy Administration (FEA) [1] [2] target the calcining and drying areas of Gypsum board production for energy improvements.

The measures recommended include the following:

(1) in the calcination step:
- improve combustion methods
- minimize heat losses in exhaust stacks
- replace batch calciners with continuous calciners

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(2) in the board drying step:
- reduce gypsum content
- production of lightweight board (less water to remove)
- improve dryer efficiency
- reduce water in slurry

Since the publication of these reports in the the mid 1970's, many of these recommendations have been addressed. In the calcination step, for instance, most batch calciners have been replaced with continuous calciners. Further developments have resulted in a second generation of energy efficient calciners. Calcination operations using exhaust gas return systems to improve efficiency(3) and flash calciners, with hot gases in direct contact with the gypsum,(4) have greatly improved calcination efficiency. In the future new technology such as the use of solar energy in the calcination process may yield even greater energy reductions.(5)

In the board drying step many attempts to improve the efficiency have been noted. Methods to reduce drying time include lowering the gypsum content of the board or reducing the overall weight of the product. In either case the strength of the product is reduced. As consumer reaction to board strength and weight is variable, knowledge of the local market is required before such methods can be assessed.(6)

The energy efficiency of board dryers has also received attention. Modern natural gas fired, multi-deck board dryers can operate at efficiencies of over 70%. A study sponsored by the U.S. Department of Energy (DOE) details attempts to recover heat from the exhaust gases of a multi-deck board dryer.(7) The study showed that despite numerous mechanical problems and substantial capital investment, limited forms of heat recovery could prove economically feasible. Studies on the use of a heat pump in the drying of plaster blocks indicated the potential for energy reductions of up to 40%.(8) However, the capital equipment cost was approximately double that of a conventional system.(9) Experiments on the use of microwaves in the drying of board have been reported. Preliminary data indicated that the properties of the product did not change and no recalcination was observed. At present, the microwave method would be more

At present, the microwave method would be more costly, from both capital and operating standpoints, than conventional techniques.

Clearly, of the target areas in which to reduce the energy consumption in gypsum board manufacture, the reduction of the water used in slurry preparation has the greatest potential. To a large extent calciner and drier efficiencies have been optimized and any gains in these processes would be minimal. The drying of the board to remove excess water consumes the large majority of total energy used in production. Minimizing the water used in slurry preparation has been investigated but there are likely significant gains still possible. One objective of this review is to recommend areas of study which may yield methods of reducing stucco water demand.

4.4 Reduction of the Water Demand of Calcined Gypsum

4.4.1 Background Information

The water present in a stucco slurry has two functions. First, about 19% of it is used to rehydrate the calcined gypsum to the dihydrate form. The remaining water is needed primarily to give the slurry the necessary flow characteristics. Reducing the water content of a slurry is not a simple independent procedure. Reduction of the water demand of a stucco would have an impact at several stages in the board manufacturing process including changing the shear energy during mixing, increased demands on foam generation, changes in stucco particle disintegration and changes in the slurry setting behaviour and accelerator response. All these factors are integrally connected. For instance, methods to reduce stucco water demand, such as exposure to humidity or adding soluble salts to the calcination kettle can significantly reduce water demand. However, these treatments decrease the activity of a stucco, lower the strength of the product and decrease the bond at the gypsum/paper interface. These detrimental effects prohibit use of these treatments in gypsum board production.

When a stucco is mixed with water, the stucco particles disintegrate or break apart into many fragments. These small hemihydrate particles begin to dissolve and the dihydrate begins to crystallize out. The strength properties of the finished product depend on the crystal growth of the

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dihydrate. Best strength is achieved when there is a large surface area of hemihydrate available for dissolution. This property, however, is directly opposed to a low water demand stucco. i.e. as disintegration increases and surface area increases, the water demand also increases.(11) Although the most important factor affecting the flow properties of a slurry is the volume fraction of solids,(10) other factors such as degree of disintegration, particulate surface properties and electrical charges also have a significant impact. The setting properties of a stucco may be modified somewhat by addition of accelerators, or retarders but unless stucco has sufficient "activity" (i.e.disintegration) suitable strength properties will not be achieved. Thus, water demand is not the only criterion by which potential stucco treatments should be evaluated. The impact of the treatments on the entire manufacturing process must be considered.

For the purposes of this review stucco treatments are divided into three categories depending upon where in the process they occur. These categories are:

1. pre stucco treatments (before or during calcination)
2. post stucco treatments (immediately after calcination)
3. slurry treatments (during final stucco-water mixing).

4.4.2 Pre Stucco Treatments

The addition of superplasticisers before or during calcination to reduce water demand is reported in a British Patent.(12) The commercially available plasticisers Lomar D, Parvan and Melmet L10 decrease the surface energy of the stucco particles by either changing the surface charge on the solid particle or by forming a lubrication film at the particle surface. Lomar D was found to be the most effective plasticiser giving a water reduction of about 22%. These results demonstrated in table 1 and fig. 2 Pre-stucco addition of plasticisers had no deterious effects on either the setting characteristics or final properties of the set plaster.

TABLE 1

LOMAR D (POWDER FORM) - SUPER PLASTICIZER ADDITION TO GYPSUM PLASTER[12]

Plaster type	Chemical Analysis %			Water Demand mls/100 g	Slurry Fluidity mm spread	% Water Reduction at std Consistency
	Hemi Hydrate	Soluble Anhydrite	Residual Gypsum			
Normal Plaster without addition of superplasticizer	64.6	7.1	2.5	70	68	-
Normal Plaster LOMAR D superplasticizer added after calcination						
0.05% LOMAR D *	64.6	7.1	2.5	67	79	6.8
0.1% LOMAR D *	64.6	7.1	2.5	66	88	11.1
0.15% LOMAR D *	64.6	7.1	2.5	64	93	12.6
Plaster with LOMAR D superplasticizer added before calcination						
0.05% LOMAR D *	64.3	7.9	2.3	66	84	8.9
0.1% LOMAR D *	62.6	9.5	1.0	64	94	16.3
0.15% LOMAR D *	64.6	7.5	2.5	62	107	21.6

* LOMAR D Powder Analysis: 84% Napthalene sulphonate polymer
11% Sodium sulphate
5% Free moisture

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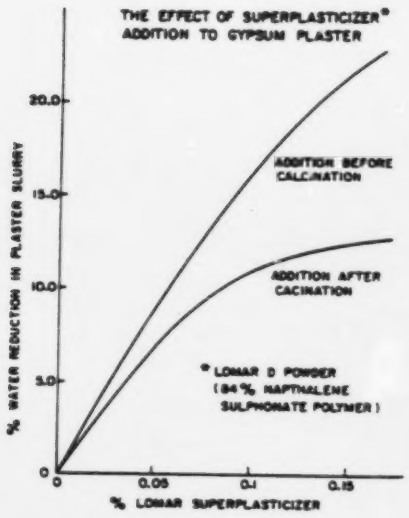

Fig. 2

The Effect of Superplasticizer Addition to Gypsum Plaster(12)

4.4.3 Post Stucco Treatments

Stucco treatments performed after calcination (Post stucco treatments) consist mainly of artificial ageing of the stucco. Artificial ageing involves the treatment of freshly calcined stucco with small amounts of water (1-10%). This treatment serves to reduce the water demand of the stucco. Ageing is believed to repair some of the structural disorder in the stucco particles caused by calcination.(13) Ageing, however, also tends to reduce the strength of the final product.

A 1978 U.S. patent(14) describes a technique for ageing stucco in which only one half of the feed stucco is treated. Water treating half of the stucco was found to give a product with better strength properties while reducing water demand. Once water treated, the stucco is returned to the main stream and allowed to heal several minutes before mixing. The patent claims that optimum water treatment occurs with 3.5 water addition and 20 minutes of healing time. These relationships are illustrated in figures 3 & 4.

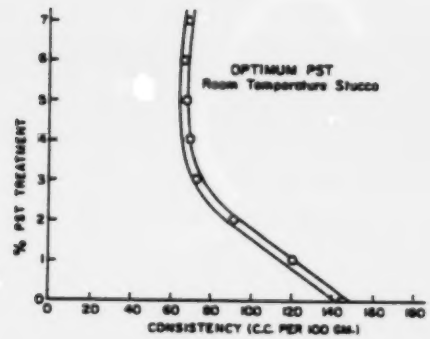

Fig. 3

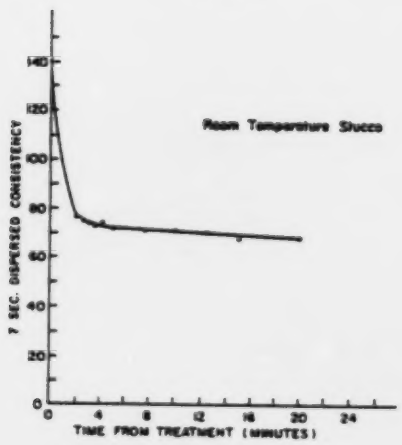

Fig. 4

Optimum Water Treatment and Healing Time Curves(14)

Details of a shearing mixer used in water treatment of stucco are given in another U.S. patent.(15) The mixer consists of a drum in which the stucco is mixed with an outboard motor propeller (fig. 5). Between 50 and 75% of the plaster destined for the board line is diverted to the mixer

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where it is treated with a stream of water. About 6% water is added before the stucco is returned to main stucco stream. The treated stucco is allowed to heal for 1-2 minutes before mixing occurs. The important innovation in this mixer is the rapid treatment of small amounts of stucco to produce a stucco with a lower water demand.

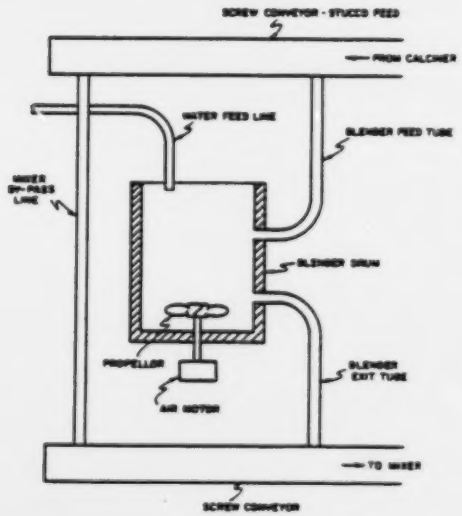

Fig. 5 STUCCO BLENDING APPARATUS (15)

A further development in the artificial ageing involves drying the stucco after water treatment to allow it to be stored before use.(16) After drying, the stucco is ground to 2.5 to 3 times the original surface area. Pre-slurry grinding restores stucco activity and increases strength development to that of the original stucco. The degree of grinding is dependent upon the original strength characteristics of the stucco and the degree of water treatment. This method was found to reduce water demand up to 26%. Details are presented in table 2.

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TABLE II

EVALUATION OF STRENGTH DEVELOPMENT AND WATER DEMAND FOR GYPSUM GROUND AFTER WATER TREATMENT[16]

	Untreated Material with 3500 (cm^2/gm) Surface Area	Partly Healed *	Healed Dried with 7000 (cm^2/gm) Surface Area	Healed Dried with 9600 (cm^2/gm) Surface Area
Water Demand lbs./M sq.ft. of ½" board	1244	1128	991	915
Dispersed Consistency - cc.	130	109	85	85
Set Suddeness ^{o}F/minute	9.4	7.7	7.3	10.0
Slurry Cube Strength - psi at 42.1 lbs./$ft.^3$ Density	798	638	590	822

*About 2% by weight of free water was added, but the material was not dried or ground because strength decreases expected on full 3% free water addition and healing would render board production line inoperable.

Two practical applications of post stucco treatment accompanied by grinding are used by the United States Gypsum Company.[17]. In the first method the stucco is passed through a Shugi blender where water is added. After a short healing time the stucco is dried in a hot air plenum. The treated stucco is collected in an air cyclone and moved to storage bins. Before use, the stucco is ground in an entolator mill to a Blaine surface area of 9,000 cm^2/g. The characteristics of the product formed using this method are comparable to those of a product made with untreated stucco. In the second method, stucco is passed through a Shugi blender where water is added. After a short healing time the stucco is ground in the entolator mill to a Blaine surface area of 9,000 cm^2/g. The stucco treated in this manner must be used immediately ie. within one hour of treatment.

A modification of the post stucco treatment combines the water treatment step and the grinding process in a modified impact mill as illustrated in fig. 6.[18] In a plant simulation, an impact mill spinning

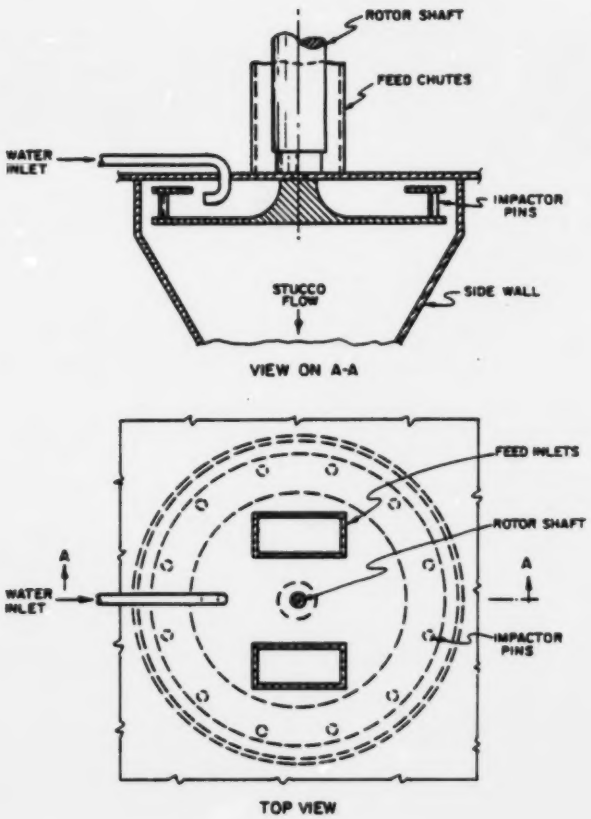

Fig. 6 IMPACTOR MILL MODIFIED TO WATER TREAT STUCCO[18]

at 4650 rpm processed 12.5 tons of stucco an hour while adding 1350 lbs of water. 5.4% water was added to the mill however only 3.2% actually adhered to the stucco. The surface area of the stucco was increased 2.86 times after treatment in the mill. The resulting product was found to have satisfactory physical properties. The net water reduction was about 22% (table III).

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TABLE III

COMPARATIVE ANALYSIS OF GYPSUM TREATED IN A MODIFIED IMPACT MILL WITH VARYING DEGREES OF WATER TREATMENT[18]

	Un-treated Control	Sample Run 1	2	3
Treatment				
Original surface area, cm^2/gm	3400	3400	3400	3400
Treated surface area, cm^2/gm		8970	9735	9735
Stucco flow tons/hour		12.5	12.5	12.5
Water flow, tons/hour		.34	.47	.47
% Free Water Added		2.7	3.8	3.8
% Free Water on Sample		1.8	2.76	3.2
Properties				
% Increased Surface area		164	186	186
Dispersed Consistancy, cc.				
7 second	142	-	67	67
60 second	192	89	85	83
% Reduced Water Demand			22	22
Machine Mixing:				
Stiffening, minutes	6	-	7	5¼
Set, minutes	13	-	15¼	14
Set Suddenness, °F/minutes	8.1	-	-	7.7
Slurry Cube Strength:				
actual p.s.i.	882	-	1760	1675
at 42 p.c.f density	793	-	635	594
% of normal	155	-	124	116

In an international patent by Bounini, the healing time required for the ageing process is reduced by the addition of solubilizing agents to the treatment water.[19] The process is based on the theory that ageing water on the stucco particle surface becomes supersaturated with $CaSO_4$. The solution acts as a medium for a mass transfer from the higher energy areas of the particle such as sharp points or edges to lower energy areas. The rate of healing depends on the rate of dissolution of the $CaSO_4$. Therefore by adding a solubilizing agent to the treatment water, the rate of transfer of $CaSO_4$ is increased, hence reducing the healing time. The use of NaOH was presented as an example (table IV and fig. 7). Healing time was reduced

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TABLE IV

COMPARATIVE EVALUATION OF STUCCO USING NaOH SOLUBILIZING AGENT[19]

Stucco Treatment	Healing Time	Surface Area	Normal Consistency	Physical Properties (as compared with fresh stucco)
Freshly Calcined	-	11800 cm^2/g	90 cc/100g	-
Stucco & 3% H_2O	4.5 min	10800 cm^2/g	73 cc/100g	Satisfactory
Stucco & 3% 0.2M NaOH sol'n	4.5 min	9500 cm^2/g	68 cc/100g	Slightly better
Stucco & 3% 0.2M NaOH sol'n	40-45 sec	9800 cm^2/g	71 cc/100g	Satisfactory

from 4.5-5 minutes to 40-45 seconds for the treatment with 3% of a 0.2M NaOH solution. The process resulted in a 21% reduction in water demand of the stucco. The resulting product was described as having satisfactory properties.

Reduction in Healing through addition of a Solubilizing Agent(19)

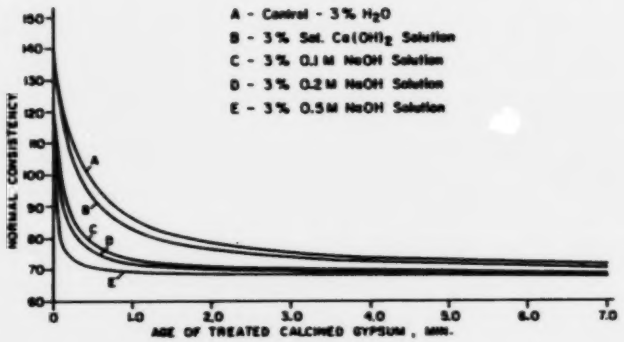

Fig. 7

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Another patent by Bounini investigates the mode of application of lignosulphonate surfactants. The surfactant Reax 88-B was applied to the stucco either dissolved in the gauging water or dissolved in the post stucco treatment water.[20] Results indicated that use of the surfactant in the treatment water resulted in a 4% greater reduction in water demand than if added to the gauging water.

Other post-stucco treatments which may have potential but are largely unexplored at this time are grinding of the stucco (with or without prior water treatment) and new methods of stucco surface modification.[6] In the case of the former, the theory is that grinding the stucco to a high surface area will diminish disintegration in the slurry mixer while providing a stucco of sufficiently high activity. In the case of the surface modification, this is a current area of research and no published information is available.

The use of higher alcohols and fatty acids as grinding aids in the gypsum treatment process was discussed by Fretsch and Randohn.[21] They found that the quantity and type of grinding aid used, and the point of introduction into the treatment process influenced the homogeneity of the stucco particle size. As a direct relationship between particle size distribution and water demand has been established[11], these grinding aids could be used to control water demand.

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4.4.4 Slurry Treatments

The last area in the gypsum board process where stucco treatment can occur is during the mixing stage before the slurry is cast on the board line. The addition of alkylene diphosphoric acids or salts during mixing of building plaster has been reported by Joseph.(22) These surfactants served to lengthen finishing times (the interval between stiffening and final set) and to reduce water demand in building plasters. An example presented in the patent detailed the use of 1-hydroxy-ethylidene diphosphoric acid (HEDP). HEDP was found to reduce water demand of the stucco up to 4% while increasing the breaking stress of the product. Details are given in Table V.

TABLE V

COMPARATIVE EVALUATION OF STUCCOS USING 1-HYDROXY-ETHYLIDENE DIPHOSPHONIC ACID IN BUILDING PLASTER PFC-2(22)

	W/P Ratio to have Fixed Consistency (15 cm < ϕ < 16 cm)	% Water Reduction	Breaking Stress on Bending Traction (Bars)	Flow Point (Minutes)	Spread Point (Minutes)	Finishing Time (Minutes)
Pure Plaster	0.600	-	7.3	14	25	11
Plaster Plus 0.05 ppm dry HEDP	0.580	2%	10.2	22	57	35
Plaster Plus 0.10 ppm dry HEDP	0.565	4%	11.4	80	140	60

(1) Test pieces keep for 2 hours in the laboratory atmosphere after moulding and before testing

(2) Flow point considered to be the moment when setting begins as determined by passing a knife blade lightly over sample. When lips of the cut did not close, settling had started.

(3) Spread point was considered to be the stage when Vicat needle penetrated no more than 5 mm into the plaster

(4) Finishing time is the time between the flow point and the spread point.

TABLE VI

EVALUATION FOR PHYSICAL PROPERTIES OF ALPHA GYPSUM AUGMENTED WITH CONDENSATE SALTS OF LOMAR D[23]

	Commercial Alpha Gypsum Composition (Control B)	Condensate Addition	
		Sodium	Potassium
Additive		11 lbs./ton	5 lbs./ton
Normal Consistency (cc/100g)	35	27	28
Set Time	21 minutes	25 minutes	25 minutes
Time of Temperature Rise After Set	28 minutes	34 minutes	36 minutes
Dry Cast Compressive Strength	7579 p.s.i.	11992 p.s.i.	12500 p.s.i.
Dry Cast Density lbs/cubic foot	102.3	117.4	116.0
Two Week Slab Discoloration			
Wet	None	Considerable	Very Slight
Dry	None	Considerable	Very Slight

The use of naphthalene sulfonic acids to reduce water content in stucco slurries is reported in two patents by Lange et al.[23,24] An example using Lomar D in an alpha gypsum slurry was presented. The surfactant was added in two forms, one as a potassium salt and the other as a sodium salt. Water reductions of about 20% were reported for both forms of Lomar D. However, the Lomar D/K_2O mixture obtained the same reduction in the plaster consistency with less than half of the quantity of surfactant. Use of the potasium salt also gave a product with a greater compressive strength than that formed with the sodium salt.[5]

Other applications of surfactants to reduce water demand have been cited.[17,25] Although proven effective in reducing gauging water, the price and deleterious effects on the product make them a less viable alternative.

5. DISCUSSION AND CONCLUSIONS

The reduction of stucco water demand has been widely studied and significant technical advances have been recorded. However, associated

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disadvantages often prohibit the practical application of these developments. A summary of the advantages and disadvantages of stucco treatment methods is presented below.

Treatment	Advantage	Disadvantage
Pre-stucco	- Minimal capital outlay - easily tested and incorporated into board line - flexible - little energy input	- variable cost increase - some deleterious effects on product - manufacturer is dependent upon supply and price of surfactant
Post-stucco	- minor capital expenditure - minor fixed operating cost - practical examples exist	- increases material handling - inflexible - maintenance and repairs on equipment - difficult to test and incorporate into board line.
Slurry Treatments	- no large capital outlay - flexible - already in use (expertise available) - easily tested and incorporated into board line - little energy input	- variable cost increase - deleterious effects on products - manufacturer is dependent upon surfactant supply and price

In general, the pre-stucco and slurry treatments depend on surfactants and often their high cost negates any cost savings from an energy standpoint. The USG post stucco treatment is currently the only viable method which does not rely on surfactants. Other post-stucco methods such

as stucco grinding are not yet sufficiently developed to make economic judgements. A formula, obtained from U.S.G., by which the economics of a stucco treatment may be judged, is as follows:

$$\text{Break even point}^{*} = 0.17 \times \text{water reduction } (\text{lb}/1000\ \text{ft}^2) \times \text{energy costs } (\$/\text{million BTU})$$

*The break even point of a treatment method occurs when the figure generated by this equation is equal to the capital cost of the system. This does not include future savings as a results of energy reduction.

The important parameter in this equation is energy costs. If a particular gypsum board plant is operating in a location where low cost energy is readily available, such as Alberta, the use of surfactants is unnecessary. In areas such as Ontario, where energy is more expensive, the use of surfactants is economically justified.

The post-stucco treatment developed by USG is attractive due to its moderate initial capital expenditure, and minimal operating costs. Furthermore, although significant obstacles were encountered in the practical application of this treatment, to a large extent they have been overcome. USG is now prepared to license the technology and incorporate it into their manufacturing process.

Of the water reduction methods described in this review, the post stucco treatments described by U.S.G. have, at present, the greatest potential for installation in a board line. Other stucco treatments discussed although sound in theory, have yet to be proven to economically reduce stucco water demand at the plant scale level. Of these techniques, stucco grinding and new methods of surface treatment have shown promise in preliminary studies and warrant further investigation. Because of the competitive nature of the gypsum industry in Canada, there is little technology transfer between companies and the best way to benefit the industry as a whole would be to have research sponsored outside the industry for publication in the public domain.

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Based on the results of the research presented in this paper, significant reductions in stucco water demand have been achieved. These reductions translate into an energy savings in the overall gypsum board process. However further research into water reduction technology is required, and the outcome can only serve to make the gypsum board manufacturer a more cost effective producer, better able to compete in the marketplace.

Conclusions derived from these investigations may be summarized as follows:

- o The amount of water used in gypsum board manufacture can be reduced using surfactants or by water treatment of the stucco. The use of surfactants may not always be cost effective.

- o Stucco grinding and stucco surface treatment have potential for reducing water demand but are still unproven.

6. Recommendations for Future Work

Based on the conclusions of this review, the following related laboratory studies are recommended. Such studies would provide information to benefit the Canadian gypsum industry.

1. An investigation into grinding stucco (without water treatment) prior to slurry formation

2. An investigation into the use of grinding aids during initial grinding of the gypsum.

3. An in depth study of the properties and nature of the gypsum and stucco particle surfaces. Such a study would include the influence of surface modification on water demand.

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